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A PRECIPITATION STUDY BY EVENT COLLECTION FROM REINDEER LAKE, SASKATCHEWAN

by

S. R. Shewchuk

SRC Technical Report No. 135

September, 1982

SRC PUBLICATION NO. P-780-17-B-82

SASKATCHEWAN RESEARCH COUNCIL

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ACKNOWLEDGEMENTS

Special acknowledgement must go to Donna Carlson of Nordic Lodge at Reindeer Lake, Saskatchewan for assisting in initiating this project and in so diligently carrying out the field work during the summer of 1981.

In addition thanks are due to Don Bauer of the Atmospheric Environment Service who provided all of the weather data, and the facilities whereby the twenty-four hour back-trajectories were computed.

James Ross of the Saskatchewan Research Council was primarily responsible for graphics and general report organization.

ABSTRACT

Event collection of precipitation was carried out during the summer of 1981 near Southend, Saskatchewan on Reindeer Lake. The rain was chemically analyzed for major ions of sulphate and nitrate. In addition, sample pH values were determined. While sulphate and nitrate concentrations in the rain were generally quite variable, most of the sulphate was in the concentration range 0.30 to 0.72 mg/L and most of the nitrate was in the range 0.12 to 0.40 mg/L.

One day back-trajectories were drawn for the periods corresponding to the ending of precipitation. In general it is seen that northerly air trajectories corresponded to more dilute rain samples, than southerly air trajectories. The influence of naturally occurring forest fires is shown to significantly influence background rain chemistry.

All rain samples collected can be termed acidic as based on electrode pH determinations, with a range of values of 4.82 to 3.90. However, the low solution ionic conductivities and other well-known difficulties in measuring pH of natural systems bring these values into question. Due to the highly sensitive character of the natural ecosystems significant increases in research activities for the area are recommended.

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INTRODUCTION

The concept of acidic deposition (or acid rain) and its implications and potential for Saskatchewan has been recently addressed by several authors (Hammer, 1980; Shewchuk, et al, 1981). The area of northern Saskatchewan has been identified as a region possessing ecosystems that are highly sensitive to acidic deposition. This is primarily due to the presence of a granitic bedrock and sandstone structure known as the Precambrian Shield.

Industrial emission of sulphur and nitrogen oxides travel hundreds and thousands of kilometres from the emitter source (Smith and Jeffrey, 1975). These gases are oxided by atmospheric processes primarily to sulphuric and nitric acids (Likens, et al, 1979) and fall onto various ecosystems as an acid particle (dry deposition) or are scavenged out of the rain (wet deposition), consequently rain in areas influenced by this process is more acid than natural.

It is important to study the rain chemistry of northern Saskatchewan for by this means the degree of acidity and the potential for ecosystem effects can be readily understood and documented.

Historically natural rain is considered to have a pH of 5.6. This is essentially the equilibrium value of carbon dioxide with pure water. Carbon dioxide is a trace gas in a natural atmosphere and has a concentration of approximately 325 ppm. However, recent studies (Charlson and Rodhe, 1982) have indicated that carbon dioxide may be less of a factor in controlling natural acidity than the low concentrations of sulphur dioxide which are found in the atmosphere in concentrations in the order of 1 ppb (Aneja, et al, 1982), the primary concept being that carbonic

acid is a weak acid in an aqueous solution while sulphuric acid is a strong acid. Hence, lower concentrations of the strong acid control the hydrogen ion concentration of the sample.

There are significant point source emitters of sulphur and nitrogen oxides in western Canada that do impinge upon the highly sensitive ecosystems of northern Saskatchewan (Shewchuk, 1979). The Environment Canada document entitled "Still Waters" (1981) described the major sulphur emitters of the region. They are: a metal smelter at Thompson, Manitoba at 359,000 tonnes per year, a metal smelter at Flin Flon, Manitoba at 212,000 tonnes per year, and two oil sands plants at Fort McMurray, Alberta emitting at 134,000 tonnes per year in total. While the metal smelters will in all probability remain stable from emissions perspectives into the future, (Shewchuk, et al, 1981), the oil sand area of Alberta, which is immediately upwind of the highly sensitive Precambrian Shield, has grown rapidly within the last decade and is likely to increase significantly in the next several decades (Sandhu, 1979).

During the summer months of 1981, the fishing-camp owners located at the town of Southend on Reindeer Lake, Saskatchewan volunteered their services to collect precipitation on an event basis. The chemistry of the precipitation from the point of view of acidic anion precursor compounds, primarily inorganic sulphate and nitrate was studied.

PROCEDURES

All precipitation samples were collected on an "event basis". For the purposes of this study, only, an event was defined as beginning immediately after the precipitation started and ended just as it stopped. Precipitation was collected in tri-pour beakers which were 400 ml in size. The beakers are disposable and constructed of polypropylene plastic. It is particularly suited to inorganic ions and metals precipitation analysis.

In the field the beakers were mounted on a stand and placed approximately 1.5 metres from the ground surface in an open area. Effects of building and vegetative splash-off were minimized. Nordic Lodge at Reindeer Lake is approximately 8 km west of the town of Southend (population ≈600), It is accessible by roadway. The sample was preserved after collection by transferring it to a nalgene bottle and sealed with a cap. The nalgene bottle with sample was then frozen, up until the time just prior to chemical analysis.

Chemical analysis for the sulphate was by ion chromatography (detection limit <0.1 mg/l for $SO_4^{=}$) and for nitrate was by cadmium reduction (detection limit <0.02 mg/l for NO_3^{-}). The pH of the sample was determined with standard glass electrode instrument.

RESULTS

The geographic location of the collection station (Southend) is shown in Figure 1. The precipitation amounts and frequency distribution for the area are illustrated by Figures 2 and 3, which show data collected at Whitesand Dam and Island Falls. As shown in Table 1, most of the major storm occurrences at Southend were collected during the summer of 1981.

Precipitation chemistry for sulphate, nitrate and pH is shown in Table 1, along with the date of occurrence, approximate amount of collection, and comments from the field observer. The field observer was to comment mainly on the beginning and ending of when the sample collection device was exposed to the precipitation. In addition, the observer was to comment on any other interesting phenomena which were occurring at the time of rainfall.

At a time corresponding to the approximate ending of a precipitation event, air mass back-trajectories were drawn (see Figures 4 to 13, inclusive) for a 24 hour period. Trajectories constructed the history of the air mass within which the precipitation developed. In most cases the times for beginning and ending of precipitation were recorded. The trajectories were calculated from the surface geostrophic wind field. Geotrophic winds as determined from surface synoptic maps represent approximately the mean atmospheric flow patterns at the top of the planetary boundary layer. The pressure patterns (isobaric contours) determine wind direction in these calculations. Each one day back-trajectory is composed of four 6 hour periods (taken at normal synoptic hours).

Table 1 Event Precipitation Collection from Reindeer Lake, Saskatchewan

Sample Number	Date	Amount (approx. ml)	Comments (field observer)	Analyte SO_4^{2-} (mg/L)	Analyte NO_3^- (mg/L)	pH (electrode)	Back trajectory Quadrant
1	June 5	20	1:45 p.m.	0.42	1.30	4.82	NW
2	June 5	35	8:00 p.m.	0.48	0.25	4.52	NW
3	June 7	10	6:00 p.m. to 9:00 p.m.	0.30	0.19	4.84	NE
4	June 19	30	3:00 a.m. to 7:00 a.m.	0.22	0.23	4.69	SE
5	July 7	60	8:30 p.m. (quite smoky)	2.20	0.34	3.90	SE
6	July 7	60	10:00 p.m. (smoke clearing)	0.68	0.12	4.30	SE
7	July 23	80	early morning (ash and smoke)	1.20	0.34	4.08	SE
8	August 4	10	1:30 p.m.	0.46	0.39	4.28	SW
9	August 12	10	6:00 p.m. (after severe ash and smoke)	3.40	1.30	3.99	SW
10	August 30	80	7:00 a.m. to 4:00 p.m.	1.00	0.53	4.19	NE
11	September 2	40	9:45 a.m. to 2:00 p.m.	0.48	0.20	4.67	NW
12	September 23	60	midnight to 3:00 a.m.	0.72	0.14	4.51	NW

The lowest values of sulphate concentrations were taken from sample numbers 3 and 4, at 0.30 and 0.22 mg/L respectively. As seen in Figure 5 the air trajectory which corresponded to this observation number 3 came primarily as a swiftly moving air stream from the northeast from a region over Hudson Bay. In Figure 6 the air trajectory which corresponded to number 4 observation came from a southwesterly direction and came from a rather weak slow moving low system located in the northeast part of this province. The origin of this air mass was primarily from the northern portions of Saskatchewan.

The highest concentrations of sulphate were recorded with sample numbers 5 and 9, which were 2.20 mg/L and 3.4 mg/L respectively. From Figure 7 it is quite clear that sample 5 was derived from air which originated over the central portion of Alberta and sample 9 in Figure 10 was derived from air which originated from the east central regions of Saskatchewan. However, in both cases it is interesting to note that the field observer has indicated the presence of significant amounts of forest fire smoke in the general atmosphere. Sample number 7 which was taken during a smoke episode as well indicates sulphate levels in excess of 1 mg/L. However on this day the air came from a region to the east located in the central part of northern Manitoba. A sulphate concentration in the range of 0.30 to 0.72 mg/L seems to be typical of the region, and when this is occurring air trajectories for the corresponding period are originating primarily in the northwest quadrant from the town of Southend. Typical samples which illustrate this are sample numbers 1, 2, 11 and 12.

The variation of acidity as determined by pH of the sample are in the range of 4.82 to 3.90. It is seen that the rainfall of this data set

is acidic and that the greatest periods of acidity correspond to rather high levels of sulphate and nitrate in solution. The highest acidity levels are associated with the occurrence of forest fire smoke in the area. However, even rainfall that originates from relatively pristine sectors is acidic.

CONCLUSIONS

The quality of rainfall at Southend, Saskatchewan is quite variable and significantly influenced by direction from which air which comprises the storm system originates. The more dilute rainfall samples originate from rapidly moving systems from the northeast. The most contaminated samples seem to be associated with air masses that have originated in the southerly areas and are quite clearly linked to the presence of forest fire particulate scavenging by the falling raindrops.

The values of pH as determined by laboratory glass electrode measuring techniques are acidic. With the pH range for all measurement as given the rain is quite strongly acidic. However because the rainfall is a weakly buffered solution glass electrode techniques are not always the best methods to measure hydrogen ion concentration (McQuaker et al, 1982, Galloway et al, 1982 and Shewchuk, 1982).

This is the case mainly because electrode polarizations due to low conductivity impede ion flow to the necessary electrodes. However, sulphate and nitrate concentrations as determined by techniques mentioned in this report are stable and free of contamination effects, it is felt that they do represent the rain chemistry of the samples.

The air inflow into thunderstorm systems is related to surface level air quality since storms of a size sufficient to generate precipitation must have large vertical currents of surface air (Mason, 1957). Since most of the surface air of the Reindeer Lake region has passed over the granitic bedrock structure of the Precambrian Shield, it has not been contaminated by normal windblown soil dust effects as is so evident in precipitation chemistry of Southern Saskatchewan (Shewchuk et al, 1981).

Thunderstorm motion is not directly related to surface structure but by using these approaches, best estimates of air mass dynamics can be provided for this study.

Due to the extreme variability it is not possible to adequately quantify rain in this area. A great deal of more first class observational programs, and many more years of historical data are needed to quantify the situation in this part of Saskatchewan.

This work is simply preliminary in nature. It is strongly recommended that massive programs are necessary to document precipitation quality of northern Saskatchewan. In general it is seen that precipitation quality at times is near a global background value but it is influenced in a major way by factors of a regional nature, whether they be natural or anthropogenic. Since many of the freshwater and terrestrial ecosystems are highly sensitive to acidic deposition, any changes to the acid loading received by these systems will be first observed in the precipitation and air quality of this region. An increased acid loading from the atmosphere is likely to impact directly upon the ecosystems with minimal neutralization.

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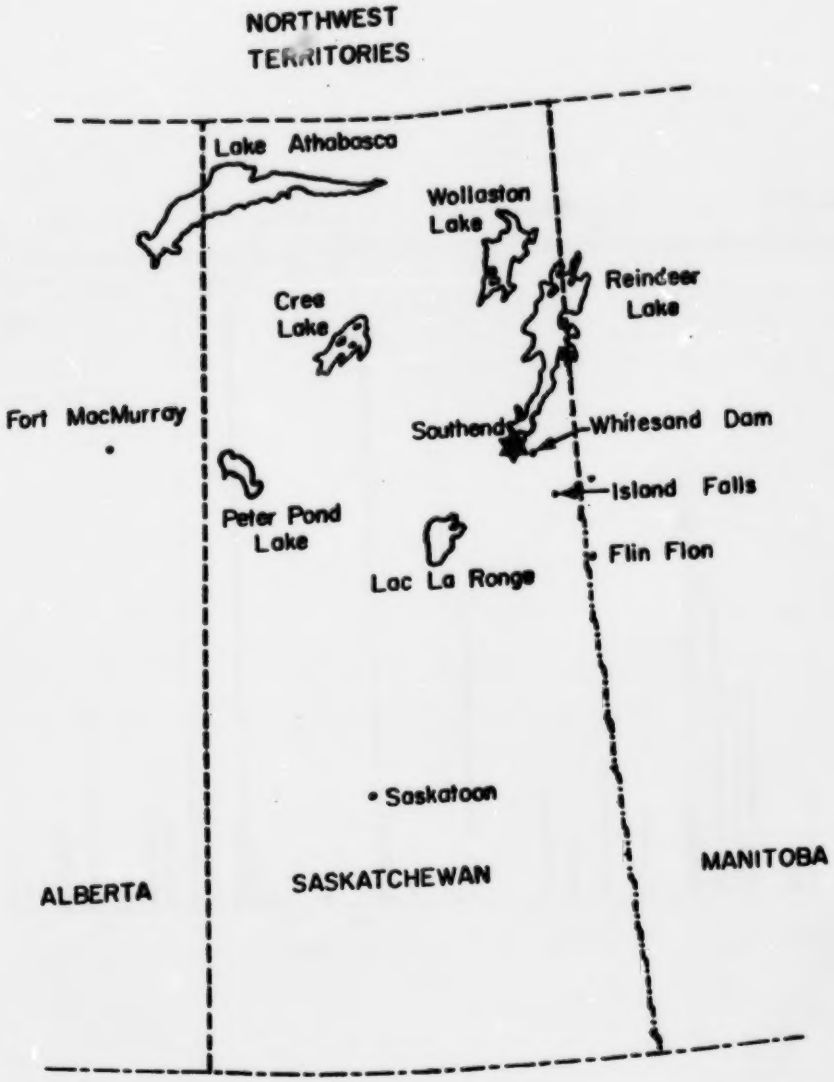


Figure 1: Location of event collection site within Saskatchewan (Southend).

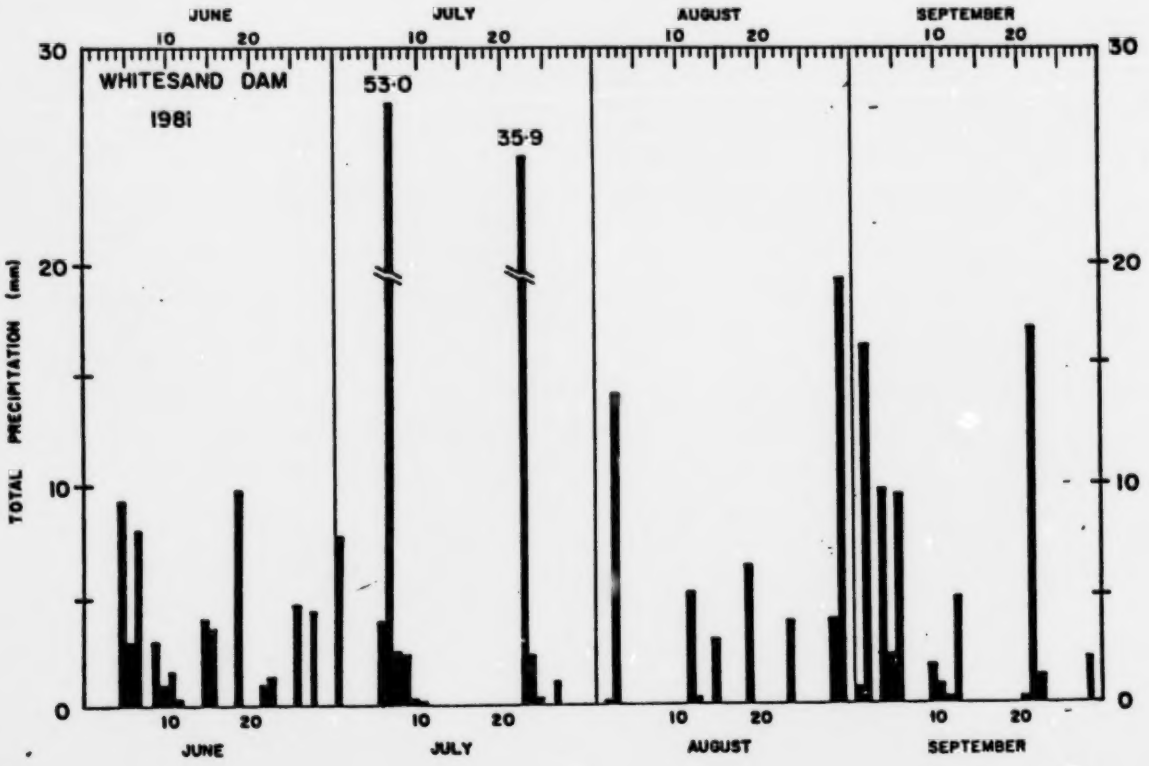


Figure 2: Precipitation amounts and frequency distributions at Whitesand Dam, Saskatchewan collected during the summer of 1981 (data from Environment Canada).

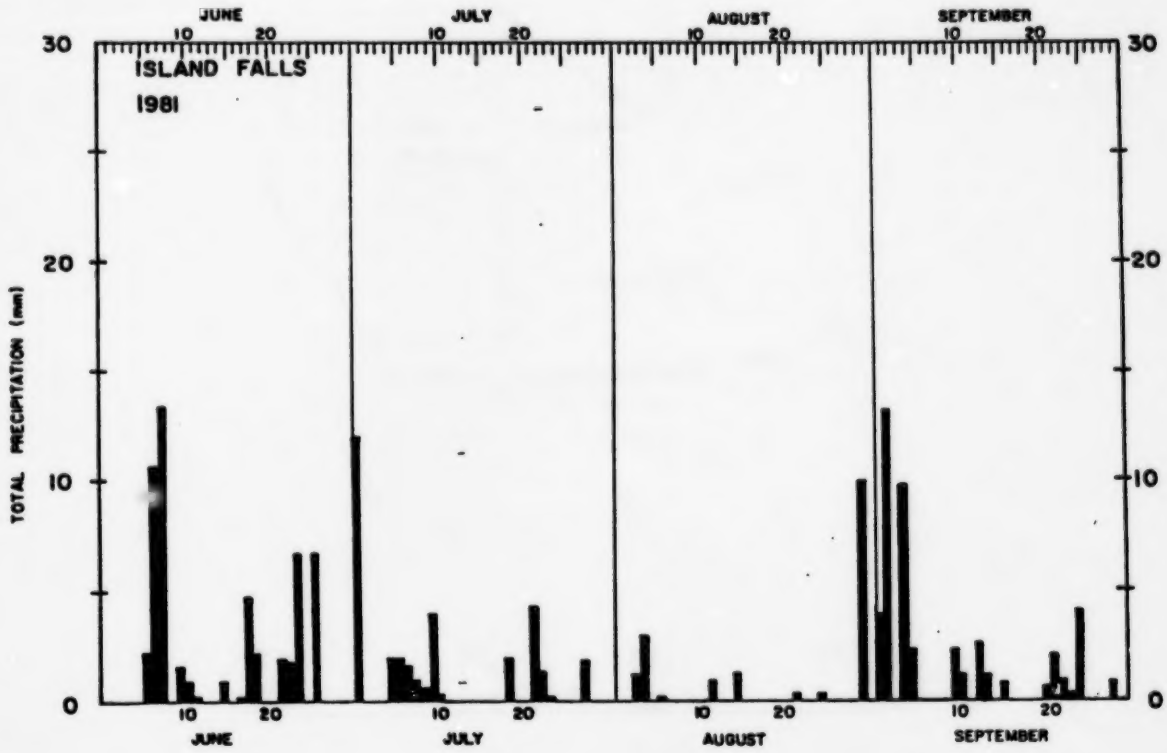
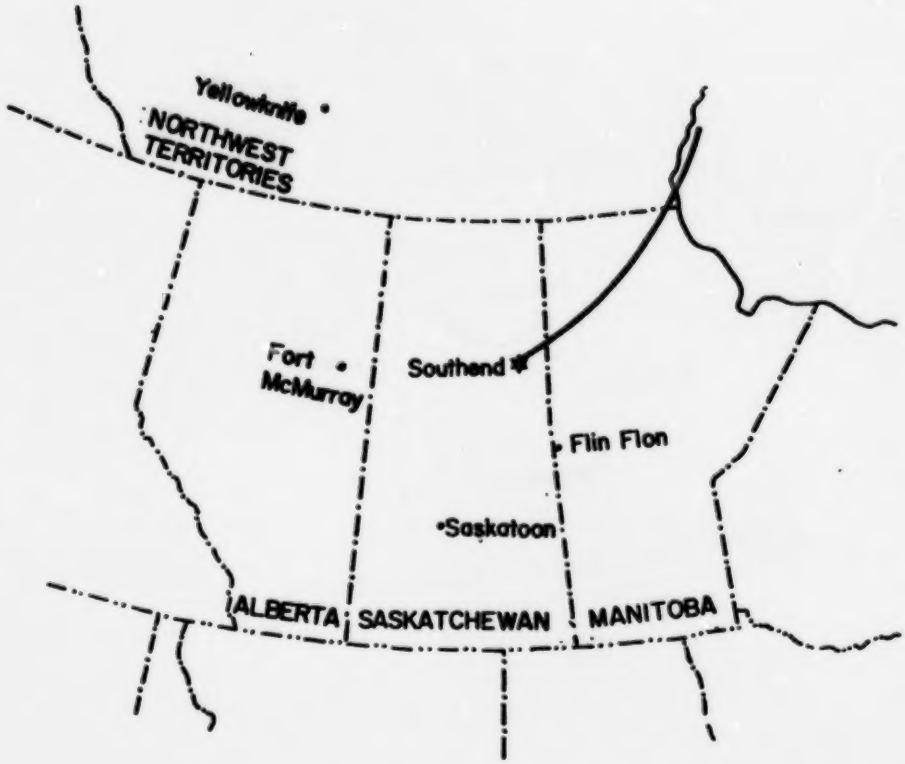


Figure 3: Precipitation amounts and frequency distribution at Island Falls, Saskatchewan collected during the summer of 1981 (data from Environment Canada).

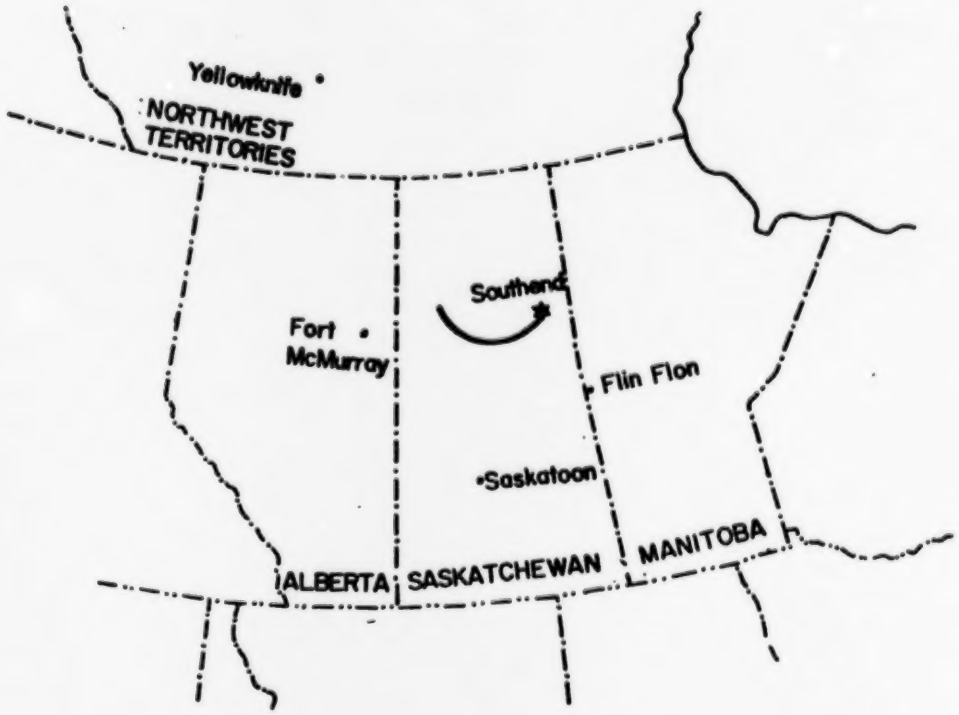
Sample Number	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	pH
1	0.42	1.30	4.82
2	0.48	0.25	4.52

Figure 4: Air trajectory for samples number 1 and 2. Trajectory initiation time was 00Z 6 June, 1981.



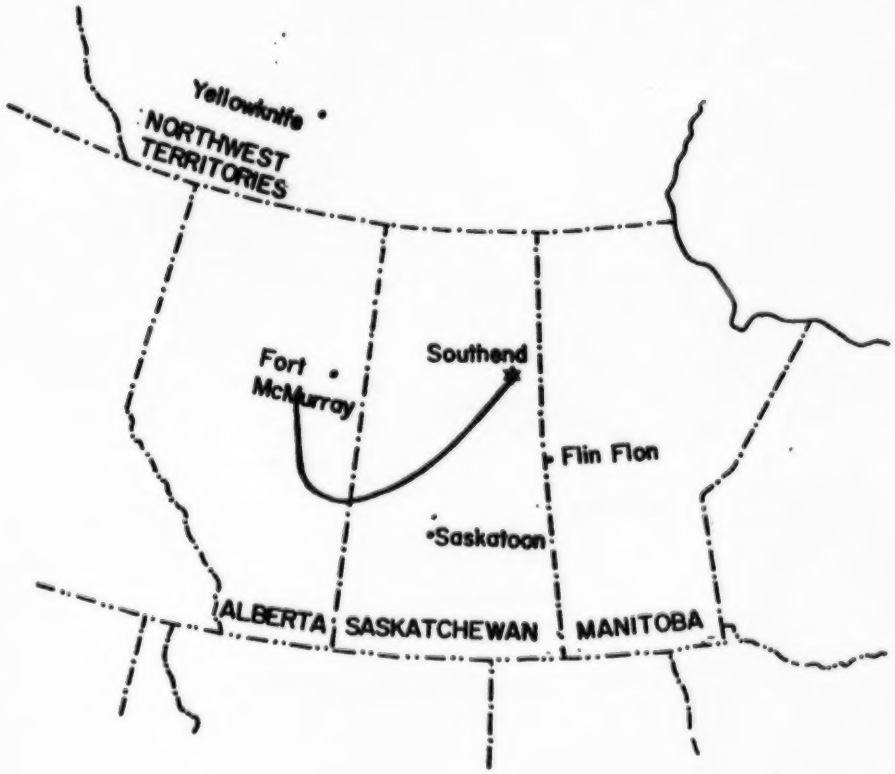
Sample Number	SO_4^{-2} (mg/L)	NO_3^- (mg/L)	pH
3	0.30	0.19	4.84

Figure 5: Air trajectory for sample number 3. Trajectory initiation time was 06Z 8 June, 1981.



Sample Number	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	pH
4	0.22	0.23	4.69

Figure 6: Air trajectory for sample number 4. Trajectory initiation time was 12Z 19 June, 1981.



Sample Number	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	pH
5	2.20	0.34	3.90
6	0.68	0.12	4.30

Figure 7: Air trajectory for sample numbers 5 and 6. Trajectory initiation time was 06Z 8 July, 1981.

Sample Number	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	pH
7	1.20	0.34	4.08

Figure 8: Air trajectory for sample number 7. Trajectory initiation time was 18Z 23 July, 1981.

Sample Number	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	pH
8	0.46	0.39	4.28

Figure 9: Air trajectory for sample number 8. Trajectory initiation time was 00Z 5 August, 1981.

Sample Number	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	pH
9	3.40	1.30	3.99

Figure 10: Air trajectory for sample number 9. Trajectory initiation time was 00Z 13 August, 1981.

Sample Number	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	pH
10	1.00	0.53	4.19

Figure 11: Air trajectory for sample number 10. Trajectory initiation time was 00Z 31 August, 1981.

Sample Number	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	pH
11	0.48	0.20	4.67

Figure 12: Air trajectory for sample number 11. Trajectory initiation time was 00Z 3 September, 1981.

Sample Number	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	pH
12	0.72	0.14	4.51

Figure 13: Air trajectory for sample number 12. Trajectory initiation time was 12Z 23 September, 1981.

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